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MALMSTROM AFB CHINOOK WIND STUDY

by

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13. Abstract: This report documents efforts to determine correlations among certain weather variables at Malmstrom AFB, MT, in an attempt to help forecast the onset of winds over 25 knots during Chinook season (October through April); only weak relationships could be found. Predictive equations based on these correlations were developed using linear regression techniques; the equations showed limited skill. USAFETAC then tried to improve the Heidke skill scores by including more predictor variables chosen by a stepwise regression technique; skill scores improved slightly, but remained below 0.50. Finally, USAFETAC looked for a favored time interval between development of a 10-mb sea-level pressure difference and onset of 25-knot gusts or sustained winds at Malmstrom; there was none.

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PREFACE

This report documents work on USAFETAC Project 9008110, "Chinook Wind Study." The study was undertaken at the request of Detachment 5, 9th Weather Squadron, at Malmstrom AFB, MT. Project analyst was Capt Gregory J. Reding, USAFETAC/DNO.

In an attempt to improve its wind forecasting capability, Det 5 had studied relationships among weather variables that might help forecast high winds associated with Chinook conditions. The Det 5 study indicated possible relationships between the following paired variables: (1) sea-level pressure differences and upper-air wind speed, (2) sea level pressure differences and surface wind speeds, and (3) upper-air wind speeds and surface wind speeds.

USAFETAC/DNO was tasked to study and verify these relationships. The results were negative; there was not enough correlation among variables to produce a predictive equation. They were also asked to see if there was a favored time interval between (1) development of a 10-mb sea-level pressure difference between Boise, ID, and Malmstrom AFB, and (2) the onset of 25-knot winds at Malmstrom. There was none.

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1. INTRODUCTION.

1.1 Overview. To improve its wind forecasting support to the 301st Air Refueling Wing, Detachment 5, 9WS, asked USAFETAC to evaluate relationships (determined in a study of their own) among upper-air wind speeds, sea-level pressure differences, and surface wind speeds at Malmstrom AFB, MT. Specifically, Det 5 asked USAFETAC to compute the correlations between: (1) upper-air wind speed and sea-level pressure difference, (2) sea-level pressure difference and surface wind speed, and (3) upper-air wind speed and surface wind speed. Further, if USAFETAC's correlations indicated a relationship between these variables, a predictive equation for each dependent variable was to be developed. An independent dataset was used to compute Heidke skill scores for these equations. Finally, Det 5 asked USAFETAC to investigate the possiblity of a predictable time interval between establishment of a 10-mb sea level pressure difference between Boise, ID, and Malmstrom AFB, and the onset of gusty winds at Malmstrom AFB.

1.2 Report Contents. This report describes the USAFETAC-determined correlations between the variables requested, equations derived to predict the each dependent variable, Heidke skill scores, and USAFETAC's attempts to improve those skill scores. It also describes the results of an investigation into forecasting the onset of gusty winds.

2. DATA.

2.1 "Gusty Winds" Defined. Det 5 defines "gusty winds" as gusts of 25 knots or greater. They will be expressed that way throughout the report.

2.2 Data Locations. Weather data came from the three stations selected by Det 5; they are listed in Table 1.

TABLE 1. Weather Stations and Types of Weather Data Used.

Station	Block Station Number	Latitude	Longitude	Elevation (meters)	Observation Type
Malmstrom AFB, MT	727775	47°30' N	111°11' W	1,075	surface
Great Falls, MT	727750	47°29' N	111°22' W	1,115	upper-air
Boise, ID	726810	43°34' N	116°13' W	874	surface

2.3 Period of Record (POR). This study used a 16-year POR (1973-88) for each station.

2.4 Data Content and Software. Weather observations from individual stations were merged by common values of year, month, day, and hour to create one large dataset that included the following information:

a. Year (2-digit; e.g., 78)

b. Month (2-digit; e.g., 01)

c. Day (2-digit; e.g., 12)

d. Hour (2-digit; e.g., 23)

e. Boise station elevation (meters)

f. Boise sea level pressure (mb)

g. Great Falls station elevation (meters)

h. Height of maximum wind speed below 8,000 ft MSL at Great Falls (feet)

i. Direction of maximum wind below 8,000 ft MSL at Great Falls (degrees)

j. Speed of maximum wind below 8,000 ft MSL at Great Falls (knots)

k. Showalter Stability Index at Great Falls (dimensionless)

l. SWEAT index at Great Falls (dimensionless)

m. Malmstrom station elevation (meters)

n. Malmstrom sea level pressure (mb)

o. Malmstrom wind speed (knots)

p. Malmstrom wind direction (degrees)

q. Malmstrom wind gust (knots)

r. Malmstrom present weather codes WW1, WW2, WW3, WW4 (dimensionless)

All statistical analyses in this project were performed with Statistical Analysis System (SAS)© software. SAS is a fourth-generation language and statistics system used at USAFETAC. All computations of correlation coefficients and linear regression parameters were done with SAS procedures specific to those purposes. Computation of Heidke skill scores was done with SAS software written at USAFETAC by Maj Walter F. Miller, USAFETAC/DNO. The weather data used was read from tape and stored on disk in SAS permanent dataset format, which is particular to SAS software. Observations from 1973 to 1986 were used as the dependent data set from which correlations and predictive equations were developed. Those from 1987 and 1988 made up the independent data set used to compute the Heidke skill scores.

2.5 Tailoring the Database. To isolate observations of high winds at Malmstrom AFB thought to be caused by Chinook conditions, the following data was deleted from the database.

2.5.1 Det 5 asked that correlations and predictive equations be developed only for observations in which the sea-level pressure difference between Boise and Malmstrom AFB was 5 mb or greater. All observations in which this pressure difference fell below that threshold were written to a separate data file for further use and deleted from the original database. USAFETAC used the separated data to produce correlations of the same variables when the pressure difference was less than 5 mb to see whether forecasting skill was sensitive to this threshold.

2.5.2 Because Det 5 declared the months of October through April "Chinook season," the study focused only on this period; observations from other months were deleted.

2.5.3 To eliminate wind gusts caused by synoptic disturbances, observations containing wind directions with an easterly component were deleted. Westerly gusts associated with synoptic disturbances such as frontal passages could not be filtered out.

2.5.4 Observations containing reports of convective weather that could produce surface gusts were also deleted. The deleted observations included those containing present weather codes of 17, 18, 19, (thunderstorm squall and funnel cloud with no precipitation at the observation time, respectively) and 80 through 99 (rain showers, snow showers, or thunderstorms of varying intensity).

3. CORRELATION STUDIES.

3.1 Variables. Det 5 requested that USAFETAC compute correlations between the following pairs of variables in the dependent dataset that meet the criteria in 2.5, above.

- Maximum wind speed below 8,000 feet above mean sea level (MSL) at Great Falls, MT, and the sea-level pressure difference between Boise and Malmstrom.
- Observations of maximum hourly surface wind speed at Malmstrom and the sea-level pressure difference between Boise and Malmstrom.
- Maximum wind speed below 8,000 feet MSL at Great Falls and surface wind speed at Malmstrom.

3.2 Correlation Coefficients and Scatter Plots. Correlation can be used to measure the strength of a linear relationship between two variables (Iman and Conover, 1983). Its value tends toward zero if there is no tendency for one variable to increase or decrease as the other variable increases or decreases. The correlation coefficient always holds a value between +1 for perfect correlation, and -1 for perfect inverse correlation. A scatter plot describes visually how the variables relate to each other. Values of one of the variates are listed in ascending order from left to right along the bottom axis of a graph, and values of the other variate are listed from lowest to highest along the left-hand vertical axis. Values of these variables from each observation are plotted as coordinate pairs on this graph. The pattern that emerges from a large number of plotted points depicts the correlation between the variables. If the points fall along an upward- or downward-sloping straight line, the correlation between the variables approaches +1 or -1, respectively. Points that are "clumped" together in no apparent linear pattern describe a correlation coefficient near zero--there is no linear relationship. Correlation coefficients and scatter plots are used in 3.3, 3.4, and 3.5 to show how the requested variables relate to each other.

3.3 Correlation of Upper-Air Wind Speed and Sea-Level Pressure Difference. For this correlation, only observations valid at 00Z and 12Z were used, since these are the only valid times of the upper-air observations. Figures 1a & b are scatter plots of the correlated variables; Figure 1a involves observations for which the pressure difference was greater than or equal to 5 mb, and Figure 1b covers those for pressure differences of less than 5 mb.

SAS computed Pearson's Partial Correlation for these variables. Partial correlation coefficients are used when more than two variates are involved in a comparison, and when we want to isolate the relationship between only two of those variates. This report compares only two variates, and the partial correlation is the correlation between the two variables. In this situation, the correlation coefficients are:

- Pressure difference 5 mb or greater: 0.51
- Pressure difference less than 5 mb: 0.34

This indicates that there is some linear correlation between the sea-level pressure difference and maximum upper-air wind speed in both cases, slightly more if the pressure gradient is 5 mb or greater. The scatter plots bear this out somewhat. The plotted points are arranged roughly along a straight line if the pressure difference is 5 mb or greater, but they show significantly less organization to go along with the lower correlation coefficient.

3.4 Correlation of Sea-Level Pressure Difference and Surface Wind Speed. From the database constructed above, the maximum value of wind speed or wind gust in an hour was identified as the "maximum hourly wind speed." This variable was then correlated with hourly values of the sea-level pressure difference between Boise and Malmstrom. Figures 2a&b show the scatter plots for these correlations.

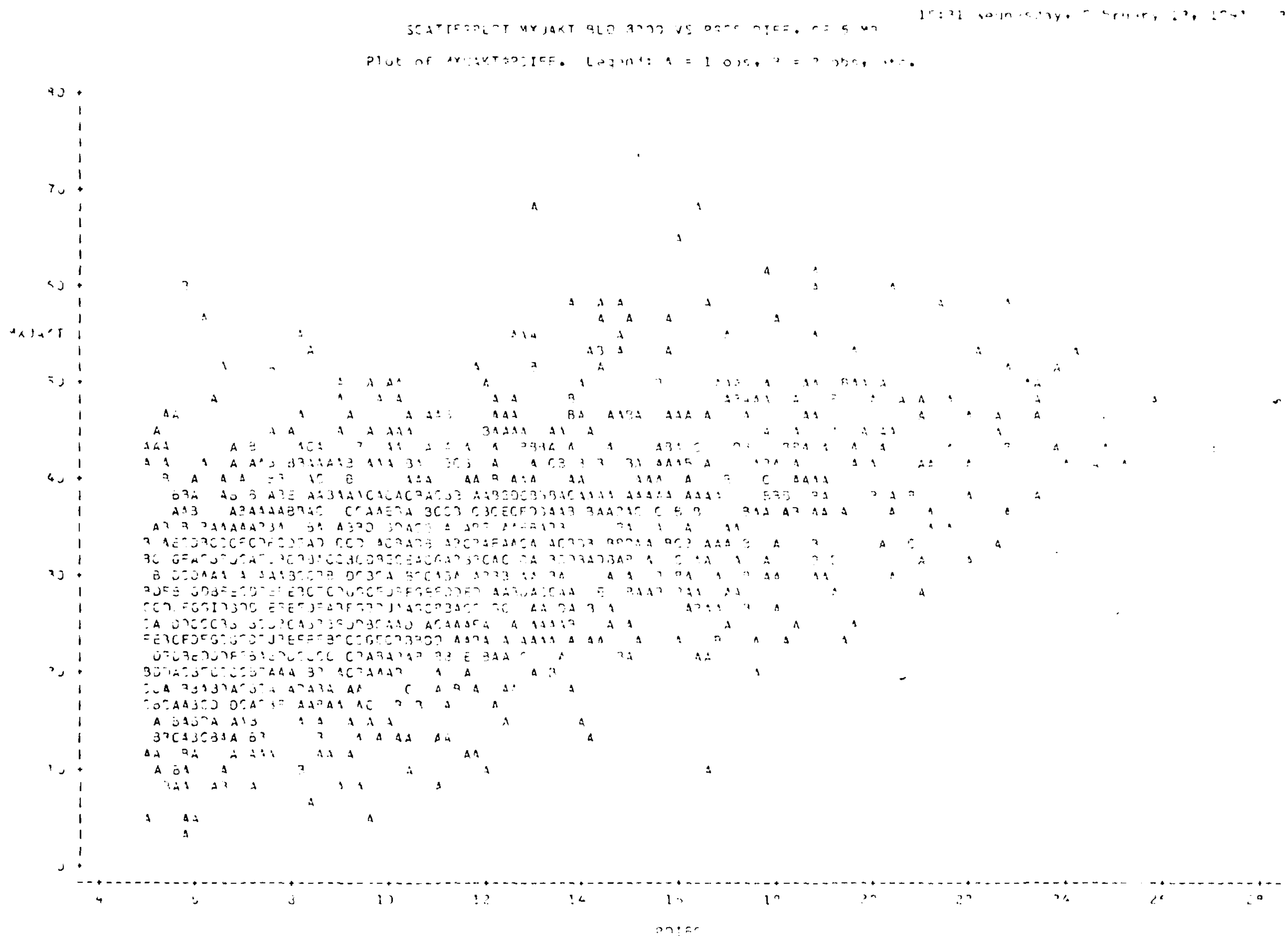

Figure 1a. Scatter plots of maximum upper-air wind speed below 8,000 feet MSL vs. sea-level pressure difference between Boise and Malmstrom for observations in which the pressure difference is ***greater than or equal*** *to 5 mb.* The letter A represents one observation at a coordinate pair; B represents two observations at that location, and so on.

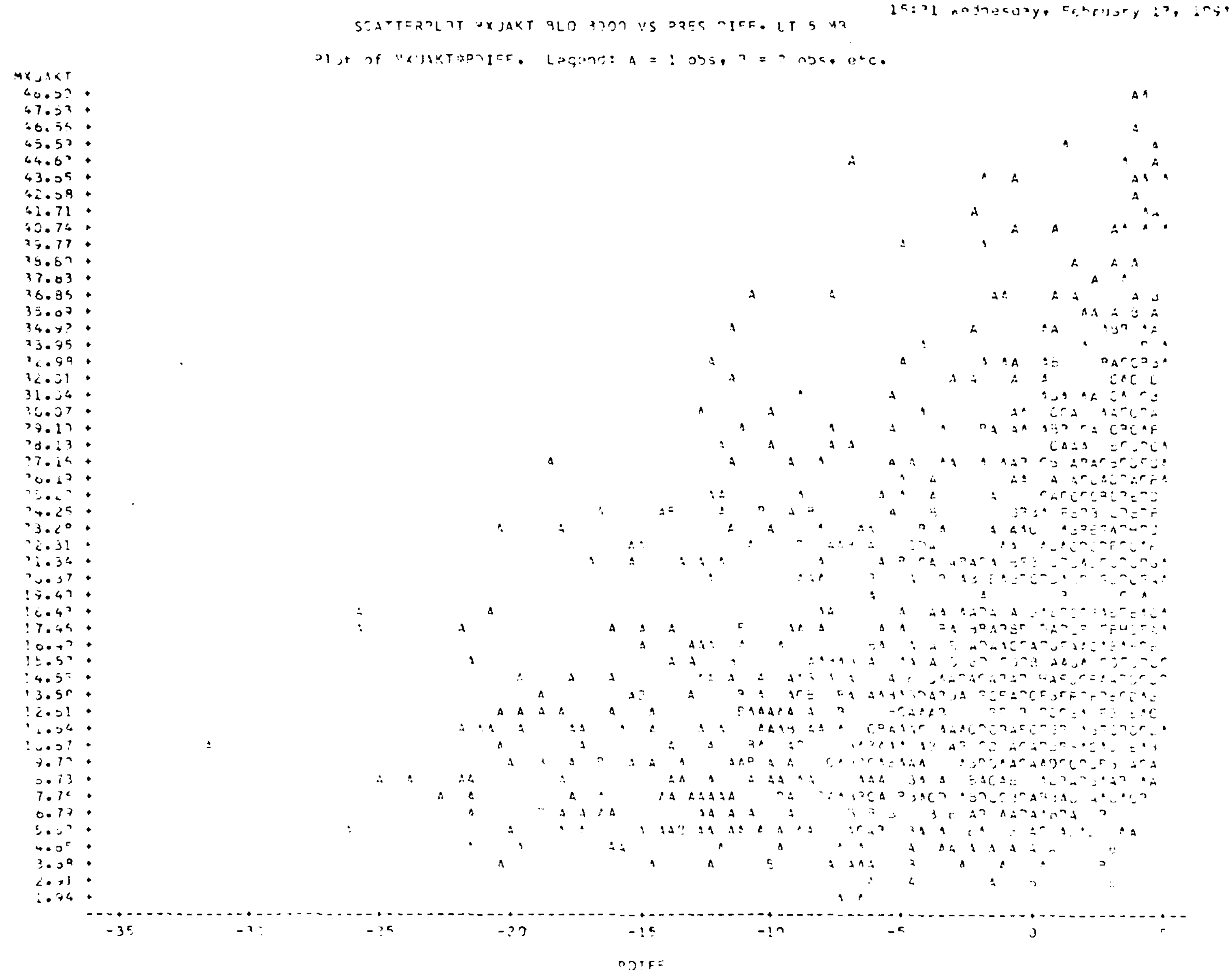

***Figure 1b.* Scatter plots of maximum upper-air wind speed below 8,000 feet MSL vs. sea-level pressure difference between Boise and Malmstrom for observations in which the pressure difference is <u>less</u> than 5 mb.** The letter A represents one observation at a coordinate pair; B represents two observations at that location, and so on.

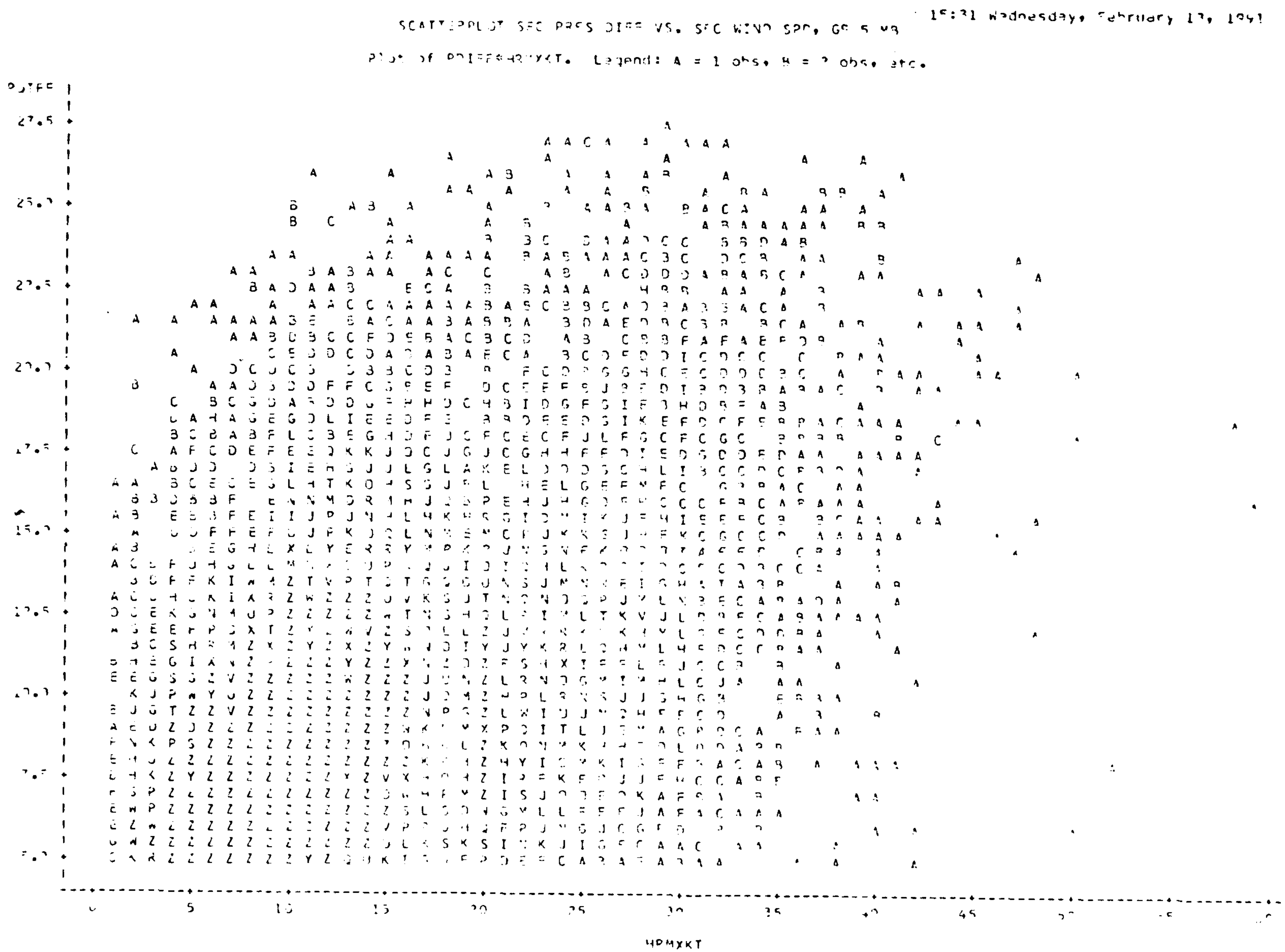

Figure 2a. ***Scatter plots of sea-level pressure difference between Boise and Malmstrom vs. maximum hourly wind speed for observations in which the pressure difference is <u>greater than or equal</u> to 5 mb.*** The letter A represents one observation at a coordinate pair; B represents two observations at that location, and so on.

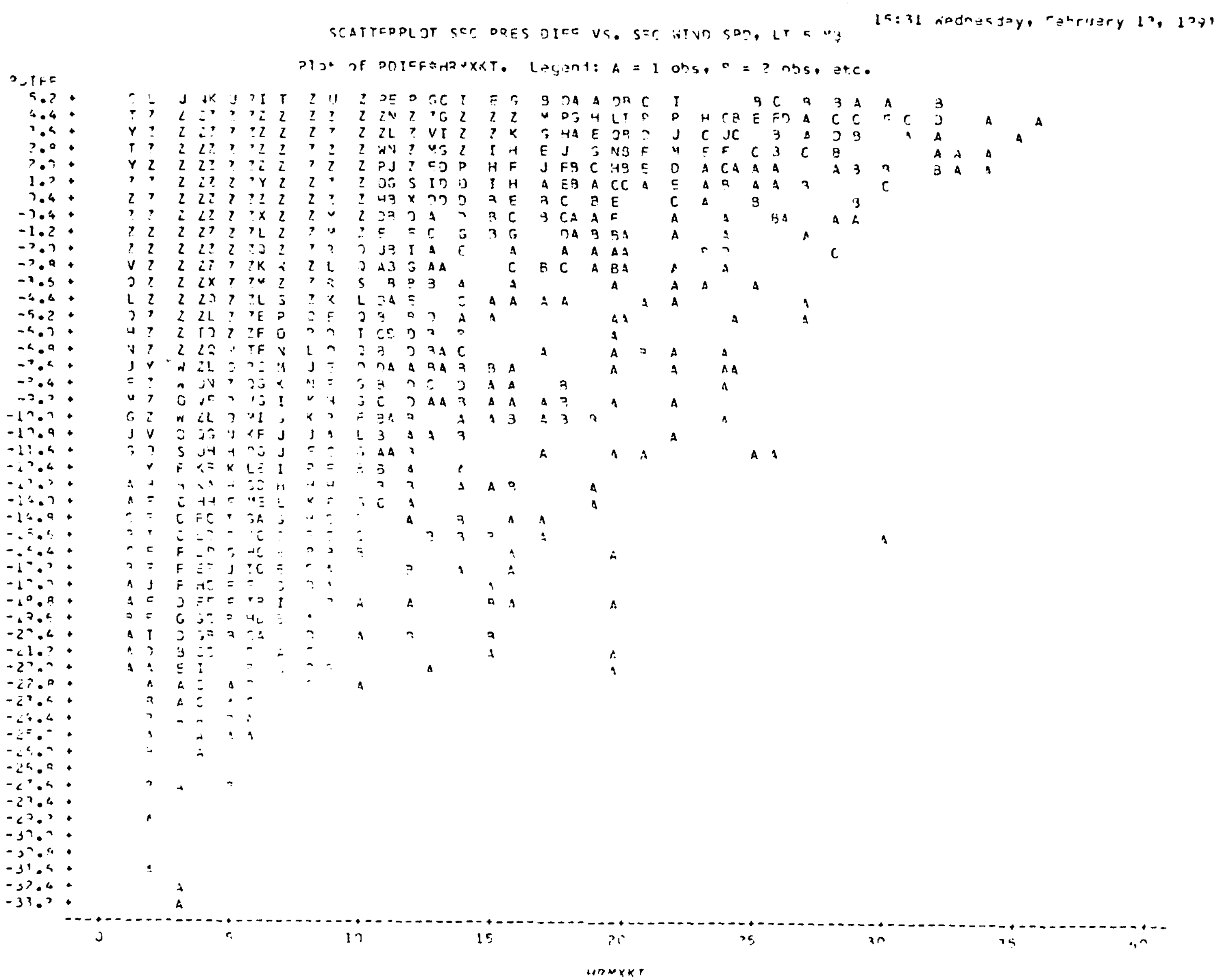

Figure 2b. ***Scatter plots of sea-level pressure difference between Boise and Malmstrom vs. maximum hourly wind speed for observations in which the pressure difference is*** ***<u>less</u>*** ***than 5 mb.*** The letter A represents one observation at a coordinate pair; B represents two observations at that location, and so on.

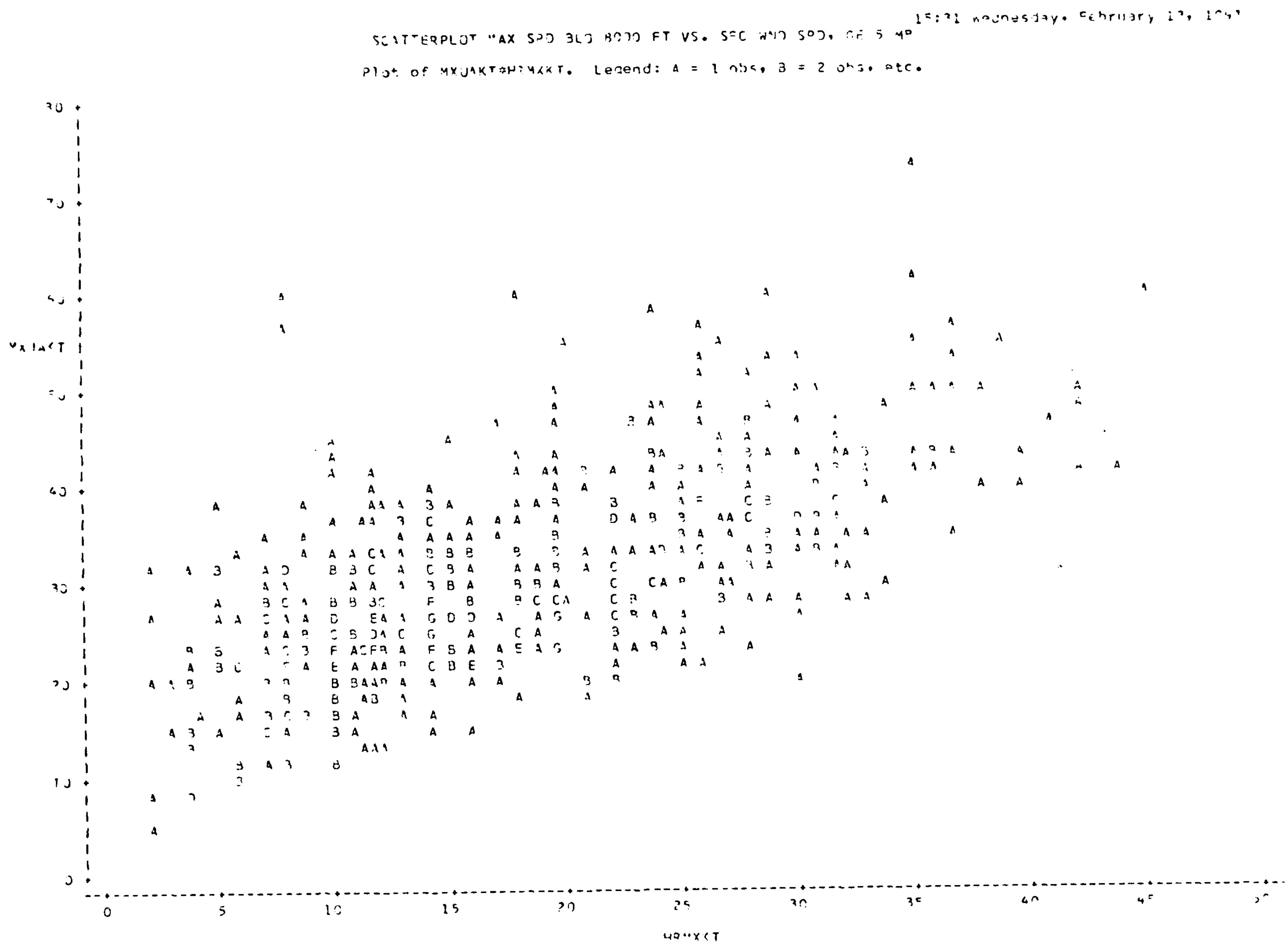

Figure 3a. ***Scatter plots of maximum upper-air wind speed below 8,000 feet MSL at 00Z and 12Z vs. the highest value of maximum hourly wind speed in the 12 hours following a sounding for observations in which the pressure difference is greater than or equal to 5 mb.*** The letter A represents one observation at a coordinate pair, B represents two observations at that location, and so on.

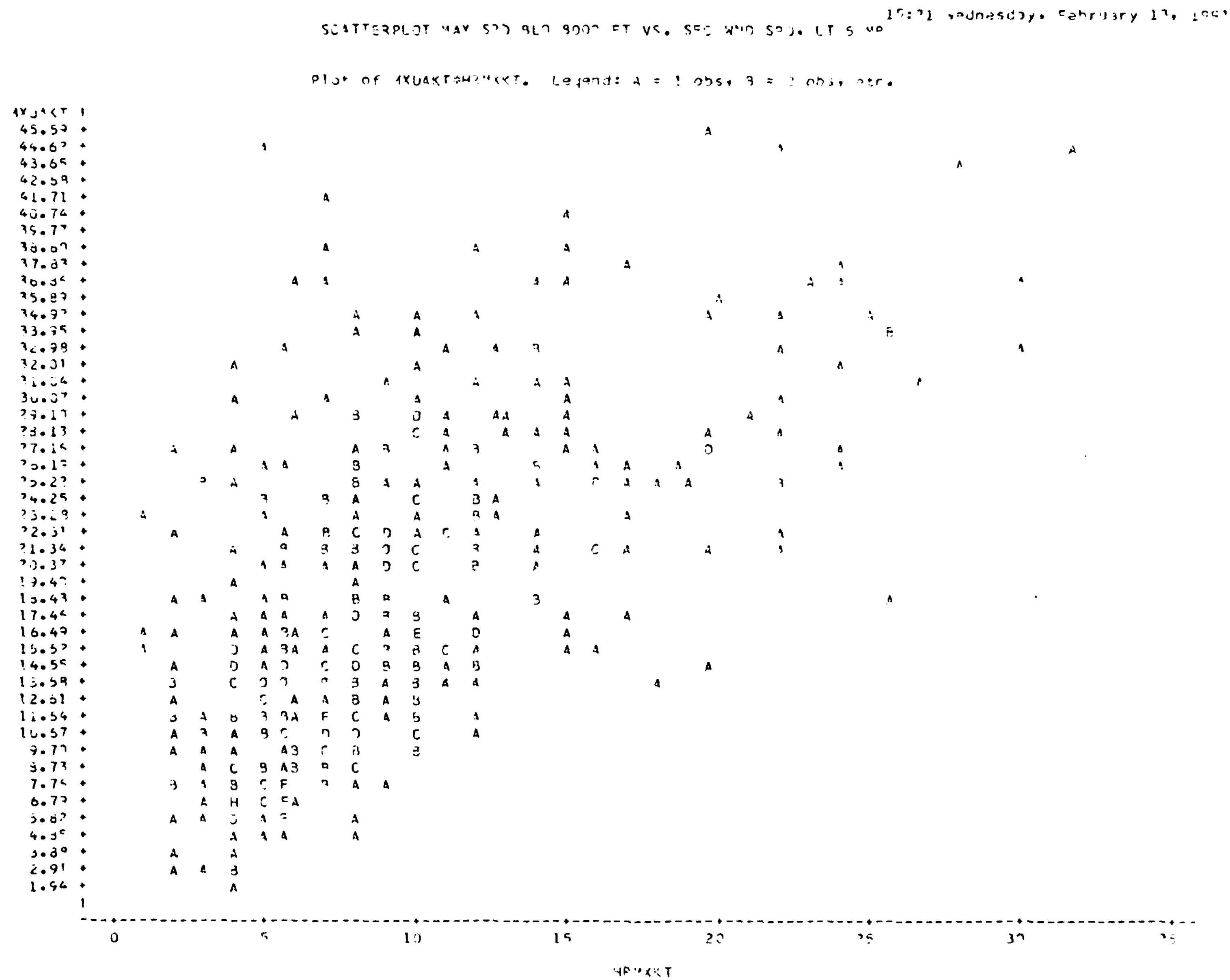

Figure 3b. Scatter plots of maximum upper-air wind speed below 8,000 feet MSL at 00Z and 12Z vs. the highest value of maximum hourly wind speed in the 12 hours following a sounding for observations in which the pressure difference is <u>less</u> than 5 mb. The letter A represents one observation at a coordinate pair, B represents two observations at that location, and so on.

3.4 Correlation of Sea-Level Pressure Difference and Surface Wind Speed. From the database constructed above, the maximum value of wind speed or wind gust in an hour was identified as the "maximum hourly wind speed." This variable was then correlated with hourly values of the sea-level pressure difference between Boise and Malmstrom. Figures 2a&b show the scatter plots for these correlations.

The correlation coefficients are somewhat lower for these variates:

- Pressure difference 5 mb or greater: 0.44
- Pressure difference less than 5 mb: 0.23

The associated scatter plots, likewise, show much less linear structure, but slight organization is evident. It appears that sea-level pressure difference and maximum hourly wind speed are not linearly correlated as well as the previous variables.

3.5 Correlation of Maximum Upper-Air Wind Speed Below 8,000 Feet MSL and Maximum Hourly Surface Wind Speed. Upper-air observations valid at 00Z and 12Z were correlated with the highest value of maximum hourly surface wind speed that occurred in the 12 hours subsequent to the upper-air sounding. Figure 3 shows the scatter plots for those observations in which the sea level pressure difference was 5 mb or greater, and less than 5 mb.

These variates are more highly correlated than any other in this study.

a. Pressure difference 5 mb or greater: 0.65

b. Pressure difference less than 5 mb: 0.61

The scatter plots show a definite linear relationship, indicating a good positive correlation between upper-air and surface wind speeds.

3.6 Sensitivity to the 5-mb Threshold. Correlation coefficients for observations in which the sea-level pressure difference between Boise and Malmstrom is 5 mb or greater are always higher than if the pressure difference is less than 5 mb, but not significantly so. The variates show only slightly more linear relationship if the sea-level pressure difference is greater than or equal to 5 mb. This threshold, therefore, may not be useful for forecasting wind speeds.

4. PREDICTIVE EQUATIONS AND LINEAR REGRESSION.

4.1 Predictive Equations. Det 5 had asked that, if any of the correlations above indicated promise of a relationship, USAFETAC would provide equations to predict the value of one variate based on the value of the other. Since the combinations of variables showed at least some linear correlation, predictive equations were developed for each, using a statistical technique called linear regression. Note that these equations do **not** forecast a variable's value at some future time based on current data, but only determine the expected value of the dependent variable at the time of the independent variable, based on a predetermined model.

4.2 Linear Regression. To predict the value of one of the variates (called the predictand, denoted y) on the basis of the value of the other variate (called the predictor, denoted x), a linear relationship could be assumed to exist between the two, of the form

$$y = a + bx \tag{1}$$

where

a = the y-axis intercept of a line on a graph

b = the slope of a line on a graph

The terms predictand and predictor are used in this discussion even though they do not relate to the forecasting of a future event, as described above. A best-fit straight line corresponding to this equation may be drawn through the points on the plot such that the sum of the squares of the deviations from the plotted points to the line is at a minimum. This line is called a "line of regression," and it represents the most probable linear relationship between y and x, assuming the deviations from the line to the plotted points are normally distributed (Panofsky and Brier, 1976). The values of a and b can be computed as statistics from a sample of data and used in equations to predict y.

4.3 Application of Linear Regression to Predictive Equations. The SAS procedure REG was used to compute the regression coefficients a and b for each pair of variables above. The dependent dataset, with a 14-year POR (1973-86) was used to find the regression coefficients in each case. Values for a and b were inserted into simple linear equations of the form of equation 1 to calculate the predictand variable based on the predictor variable.

4.3.1 Root Mean Square Error. Root mean square error (RMSE) is a measure of "badness" of the fit of the line of regression to the data it is supposed to represent. RMSE is a measure of the scatter of the points about the line of regression. The more the points are scattered, the greater the RMSE and the worse the fit of the line to the data. RMSE was computed for each of the above cases by SAS procedure REG, and is included in Table 2.

4.3.2 Variance. Variance, denoted r^2, is a measure of the "goodness" of fit of the line of regression with respect to the observed data, or how well the prediction equation mirrors reality. We are concerned with the variance of the predictand--that which is being predicted. Generally, the higher the value of r^2, the better the equation describes what actually happens in the atmosphere. A value of variance is generally thought of as the percent of the variation seen in the observed values of the predictand that can be explained by the prediction equation; e.g., a variance of 0.42 means that 42 percent of the variability of the values of surface wind speed can be explained by the equation predicting wind speed. Values of variance were calculated by the SAS procedure REG, and are included for each case in Table 2.

4.4 Heidke Skill Score. Det 5 also requested a Heidke skill score (computed using a dataset independent of the one used to compose the equations) for each predictive equation developed. Data from 1987 and 1988 was used as this independent set. The method for computing the Heidke skill score is described in AWS TR 235, Some Techniques for Deriving Objective Forecasting Aids and Methods. This method was incorporated into SAS program HEIDKE written at USAFETAC/DNO by Maj Walter F. Miller and used to compute the skill scores. The

Heidke skill score ranges from 0 (no forecasting skill) to 1.00 if all forecasts verify. The scores computed for each case are included in Table 1.

4.5 Predictive Equations, Statistics, and Skill Scores. Table 2 lists the predictand and predictor variables that Det 5 requested we study, the equation developed using linear regression on the dependent data set, the values of RMSE and variance for each, and the Heidke skill score for the equations calculated from the independent data set.

TABLE 2. Variables, Predictive Equations, Statistics, and Heidke Skill Scores for the Three Relationships Requested.

Predictand (Dependent) Variable y	Predictor (Independent) Variable x	Predictive Equation	RMSE	r^2	Heidke Skill Score
Max. upper-air wind speed 8,000 ft MSL	BOI-GFA sea-level pressure difference	$x_2 = 1.16 * x_1 + 18.21$	8.21	0.26	0.35
Max. hourly surface wind speed at Malmstrom AFB	BOI-GFA sea-level pressure difference	$x_2 = 0.83 * x_1 + 5.88$	7.38	0.19	0.21
Max. hourly surface wind speed at Malmstrom AFB	Max. upper-air wind speed below 8,000 ft MSL	$x_2 = 0.58 * x_1 + 0.32$	6.86	0.42	0.42

The skill scores and variances rank in the same order as the correlation coefficients for each set of variables. The equations show limited skill in predicting surface and maximum upper-air wind speed.

4.6 Chi-square. It is possible in any forecasting scheme that skill may result from chance. Sampling error alone makes it possible for a forecasting method to show skill on either the dependent or independent data set. It is appropriate, therefore, to test if forecast skill is the result of chance alone. To make that test, the hypothesis is made that the predictive equation actually has no skill whatsoever. The chi-square test evaluates the probability that this null hypothesis--that the predictive equation actually has no skill--is true. A full description is given in Panofsky and Brier, Some Applications of Statistics to Meteorology, 1976. The value of the chi-square test and the probability of the null hypothesis being true are shown in Table 3.

TABLE 3. Variables, Equations, and the Results of Chi-square Tests for the Three Relationships Requested.

Predictand (Dependent) Variable y	Predictor (Independent) Variable x	Predictive Equation	Heidke Skill Score	Chi-square Test	H_o Prob*
Max. upper-air wind speed below 8,000 ft MSL	BOI-GFA sea-level pressure difference	$x_2 = 1.16*x_1 + 18.21$	0.35	392.657	0.00
Max. hourly surface wind speed at Malmstrom AFB	BOI-GFA sea-level pressure difference	$x_2 = 0.83*x_1 + 5.88$	0.21	3172.036	0.00
Max. hourly surface wind speed at Malmstrom AFB	Max. upper-air wind speed below 8,000 ft MSL	$x_2 = 0.58*x_1 + 0.32$	0.42	434.061	0.00

* Probability that the null hypothesis (H_o) is true.

In Table 3, the probability that the null hypothesis--the predictive equations possess no skill at all--is so small that the SAS routine that calculates it has rounded it to 0.00 in each case. The low probability of the null hypothesis being true supports the premise that the equations possess skill, and suggests the improbability of successful forecasts being exclusively due to chance.

5. STEPWISE REGRESSION.

5.1 Improved Skill Scores. Although the above relationships used only one predictor variable and showed some skill, the skill scores were low. We therefore wanted to find simple relationships that were more skillful at predicting the dependent variables. In an attempt to do so, a stepwise regression technique was used. Stepwise regression allows several independent variables, rather than just one, to be considered as candidate predictors. This technique chooses those independent variables that explain a significant additional amount of the variance. We used the SAS procedure REG to do this, with the STEPWISE option.

5.2. Results. Table 4 summarizes the outcome of the stepwise regression procedures used to improve the skill scores for predicting the dependent variables. Included is the predictand variable, the predictor variables selected by stepwise regression, the predictive equation used, the Heidke skill score, and results of the chi-square test. As for the simple regressions above, there are three "situations" for which equations are developed:

- Predicting maximum upper-air wind speed below 8,000 feet MSL.

- Predicting surface wind speed based on predictors excluding upper-air wind speed.

- Predicting surface wind speed based on predictors including upper-air wind speed.

The differences between b and c above are by extension of the original relationships proposed by Det 5--surface pressure difference and maximum upper-air wind speed below 8,000 feet MSL were used individually as predictors of surface wind speed at Malmstrom (see Table 3).

Names of predictor variables selected by stepwise regression:

x_1 = hr	Hour of the day (Zulu)
x_2 = hrmxkt	Hourly maximum wind speed at Malmstrom (knots)
x_3 = boslp	Boise sea-level pressure (knots)
x_4 = pdiff	Sea-level pressure difference between Boise and Malmstrom
x_5 = show	Showalter stability index at Great Falls (dimensionless)
x_6 = sweat	Severe Weather Threat Index at Great Falls (dimensionless)
x_7 = maxdir	Direction of the maximum upper-air wind below 8,000 feet MSL at Great Falls (degrees)
x_8 = mxuakt	Speed of the maximum upper-air wind below 8,000 feet MSL at Great Falls (knots)
x_9 = mxuakt3	The cube of mxuakt ($knots^3$)

Names of the predictand variables in the situations requested in the SAR:

y_1 **Predicted** speed of the maximum upper-air wind below 8,000 feet MSL based on a predictive equation obtained through stepwise regression.

y_2 **Predicted** surface wind speed at Malmstrom AFB, based on a predictive equation obtained through linear regression. This equation does **not** include upper-air wind speed variables as predictors.

y_3 **Predicted** surface wind speed at Malmstrom AFB, based on a predictive equation obtained through linear regression. This equation **does** include upper-air wind speed variables as predictors.

The predictands y_2 and y_3 both are for predicted surface wind speed at Malmstrom. The equation for y_3 involves some upper-air wind speed predictors, but that for y_2 does not.

TABLE 4. Results of Predictive Equations Developed Using Stepwise Regression.

Predictand (Dependent) Variable	Predictor (Independent) Variables	Predictive Equation
y_1	x_1 = hr	
	x_3 = boslp	
	x_4 = pdiff	$y_1 = 264.79 + 0.74*x_1 - 0.25*x_3 + 1.07*x_4 + 0.26*x_5 + 0.51x_6$
	x_5 = show	
	x_6 = sweat	
	$r^2 = 0.46$	Chi-square: 117.008
Heidke skill score = 0.46		Prob of H_o*: 0.00

Predictand (Dependent) Variable	Predictor (Independent) Variables	Predictive Equation
y_2	x_1 = hr	
	x_3 = boslp	
	x_4 = pdiff	$y_2 = 138.82 - 0.91*x_1 - 0.13*x_3 + 0.80*x_4 + 0.22*x_5 + 0.03*x_6 + 0.01*x_7$
	x_5 = show	
	x_6 = sweat	
	x_7 = maxdir	
	$r^2 = 0.31$	Chi-square: 156.676
Heidke skill score = 0.31		Prob of H_o*: 0.00

Predictand (Dependent) Variable	Predictor (Independent) Variables	Predictive Equation
y_3	x_1 = hr	
	x_4 = pdiff	
	x_6 = sweat	$y_3 = -0.23*x_1 + 0.40*x_4 + 0.01*x_6 - 0.04*x_7 + 0.60*x_8 - .000042*x_9$
	x_7 = maxdir	
	x_8 = mxuakt	
	x_9 = mxuakt3	
	$r^2 = 0.51$	Chi-square: 59.665
Heidke skill score = 0.49		Prob of H_o*: 0.001

* Probability that the null hypothesis is true.

The skill score of the predictions was larger when stepwise regression was used to choose the best predictor variables. The explained variance, r^2, was also increased in each case, meaning more of the variation in the predictand could be explained with the results from the prediction equations. The increase in skill score and variance using stepwise regression over simple regression is shown more closely in Figure 4.

	Heidke skill score/r^2	
	Simple Regression	**Stepwise Regression**
Situation 1	0.35/0.26	0.46/0.46
Situation 2	0.21/0.19	0.31/0.31
Situation 3	0.42/0.42	0.49/0.51

Figure 4. Comparison of Heidke skill scores and variances.

While showing improvement, the skill scores are still somewhat low and reflect a weak relationship between meteorological variables. This is evident when using statistics to summarize a long period of meteorological data. Statistical results are derived under the assumption that there is no relationship between successive pairs of observations. Weather phenomena usually violate this assumption--occurrences like Chinook winds run in regimes, with some relationships holding at some times and different relationships holding at others (Panofsky and Brier, 1976).

6. TIMING FACTOR STUDY.

6.1 Overview. None of the relationships proposed by the customer addressed forecasting a future event--surface or upper wind speed--on the basis of current data. To consider this, the customer asked us to examine the elapsed time between the development of a 10-mb pressure difference between Boise and Malmstrom and the onset of 25-knot gusts or sustained surface winds at Malmstrom. The customer felt that if there was a particularly favored lag time, it could be included in an equation to forecast the onset of gusty winds, of the form:

Onset time of gusty wind = Constant + time the pressure difference increased to 10 mb

Det 5 also asked that a skill score be computed for this equation computed against an independent data set.

6.2 Method. SAS software was used on a dependent data set similar to that described above, except that the period of record included 1981-88. Before 1981, Malmstrom AFB reported sea-level pressure only every 3 hours. Since a timing factor was now being investigated, an equal distribution of pressure observations over all hours was needed. From this dataset, each observation in which the pressure difference between Boise and Malmstrom equaled 10 mb was located. The first instance subsequent to this time that a 25-knot wind speed or gust was observed at Malmstrom was then identified. These differences were identified as "lag times," which were grouped into bins of 1-hour length--lag times of from 0 to 1 hour were sorted into one bin, those from 1.1 to 2 hours into another, etc. Lag times of 12 hours or more were grouped into their own bin. The SAS procedure FREQ was used to compute the percent frequency of occurrence of each category of lag time.

6.3 Results. The percent frequency of occurrence of lag times are displayed as a histogram in Figure 5. As shown in the figure, there is no favored period of time between the two events, and a predictive equation could not be developed.

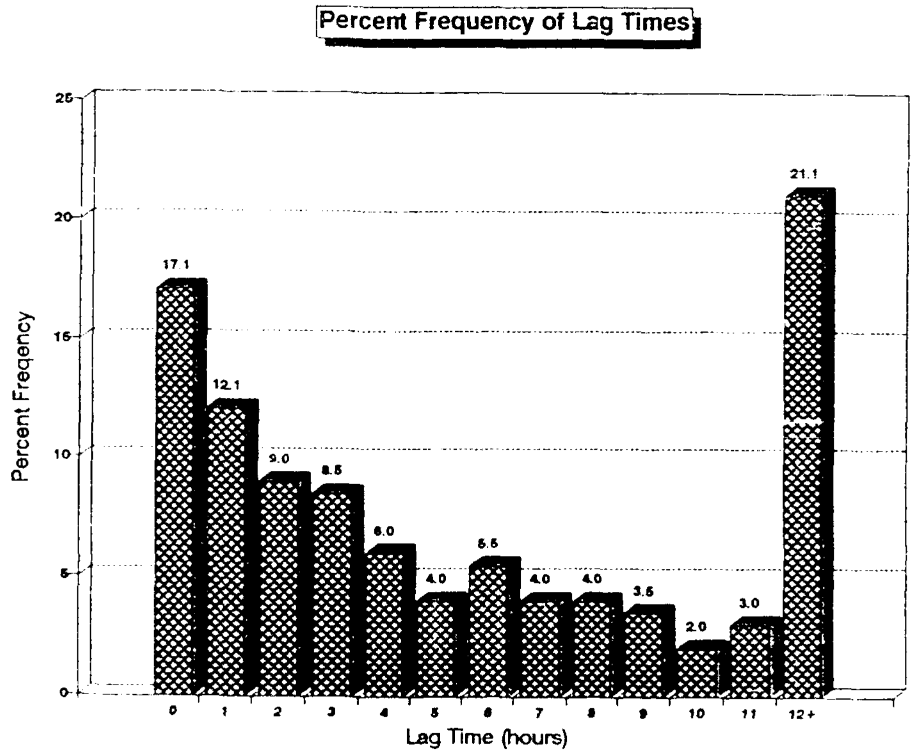

Figure 5. Distribution of lag times between the occurrence of a 10-mb Boise-Malmstrom pressure difference and the onset of 25-knot gusts or sustained winds at Malmstrom.

7. CONCLUSIONS.

In an attempt to isolate a mechanism causing high winds at Malmstrom AFB during Chinook conditions, USAFETAC/DNO investigated correlations between the three sets of meteorological variables shown below; only weak relationships were found.

(1) Maximum upper-air wind speed below 8,000 feet MSL and a sea-level pressure difference.

(2) Surface wind speed and sea-level pressure difference.

(3) Maximum upper-air wind speed below 8,000 feet MSL and surface wind speed.

Using linear regression techniques, predictive equations based on these correlations were developed; they showed limited skill.

Next, USAFETAC attempted to improve the Heidke skill scores by including more predictor variables chosen by a stepwise regression technique. Although skill scores improved somewhat, they remained below 0.50.

Finally, we looked for a favored time interval between development of a 10-mb sea-level pressure difference and onset of 25-knot gusts or sustained winds at Malmstrom. There was none.

BIBLIOGRAPHY

Iman, R. L., and W. J. Conover, *A Modern Approach to Statistics*, J. Wiley and Sons, 1983.

Panofsky, H. A., and G. W. Brier, *Some Applications of Statistics to Meteorology*, Pennsylvania State University, 1976.

Some Techniques for Deriving Objective Forecasting Aids and Methods, AWS TR 235, HQ Air Weather Service, Scott AFB, IL, March 1978.

ABBREVIATIONS, ACRONYMNS, AND SYMBOLS

a	A coefficient resulting from linear regression
AWS	Air Weather Service
b	A coefficient resulting from linear regression
BOI	Station identifier for Boise, ID
boslp	Variable name for sea-level pressure at Boise, ID
DNO	USAFETAC's Operations Applications Development Section
FREQ	SAS procedure that computes percent frequency of occurrence
GFA	Station identifier for Malmstrom AFB, MT
H_0	Null hypothesis
hr	hour
hrmxkt	Variable name for maximum hourly wind speed
ID	Idaho
maxdir	Variable name for direction of maximum wind speed
mb	Millibar
mxuakt	Variable name for maximum upper-air wind speed below 8,000 feet MSL, in knots
mxuakt3	Variable name for the cube of mxuakt
MSL	mean sea level
MT	Montana
pdiff	Variable name for sea-level pressure difference between Boise, ID and Malmstrom AFB, MT
r^2	Variable name for variance
REG	SAS procedure for linear regression
RMSE	Root mean square error
SAS	Statistical Analysis System
show	Variable name for *Showalter Stability Index*
sweat	Variable name for Severe Weather Threat Index
USAFETAC	USAF Environmental Technical Applications Center
WW1-WW4	Present weather codes
Z	Zulu

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